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ABSTRACT

This study developed predictive models on persistence and success in engineering at the end of the sophomore year by examining 11 intellective and 9 non-intellective variables. The project's long-term purpose was to contribute to the improvement of academic advising for students considering engineering majors and thus improve student retention. Usable data were gathered on 1,043 entering freshmen in the College of Engineering at Pennsylvania State University. Three models were developed to predict sophomore persistence and success at different points in time: pre-enrollment, freshman year, and sophomore year. For the pre-enrollment model, the variables best predicting success were high school grade point average, algebra score, gender, non-science points, chemistry score, and reason for engineering choice. For the freshman year model, best predictors included grades in Physics I, Calculus I, and Chemistry I. In the sophomore year model, the variables of grades in Calculus II, Physics II, and Physics I were the best predictors. Thus, it was found that the variables which are predictive depend on the student's point of progress through the first 2 years of an engineering program. (JDD)

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IDENTIFICATION OF STUDENT CHARACTERISTICS THAT PREDICT PERSISTENCE AND SUCCESS IN AN ENGINEERING COLLEGE AT THE END OF THE SOPHOMORE YEAR: INFORMING THE PRACTICE OF ACADEMIC ADVISING

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PREFACE

This report is one of two reports on the second year of a four year longitudinal study to identify predictors of persistence and success in baccalaureate engineering programs of study.

The other report on the second year "Where are They Now: A Description of the 1984 Entering Freshman Engineering Class at the End of the Sophomore Year" (Levin and Wyckoff, 1989a) provides statistics on twenty-five intellective and non-intellective variables describing the entering freshman class and those students who have persisted successfully in engineering at the end of the sophomore year. This report is similar to the first year study (Levin and Wyckoff, 1987, 1988) in that it provides predictive models on persistence and success in engineering. This study differs from the first year study in that the models predict persistence and success at the end of the sophomore year with the number of independent variables increasing from fourteen to twenty.

In order to reorient the reader to the need for and the purpose of this longitudinal study on students pursuing engineering the Introduction and Statement of the Problem sections of the first report (Levin and Wyckoff, 1987) are restated.

INTRODUCTION

Original studies attempting to predict college grades of engineering students date back to early in the 20th Century (Mann, 1918; Stoddard and Hammond, 1930). These attempts led to the development of a testing movement in engineering and the design of tests for the selection of engineering students. In conjunction with the development of such tests as the Engineering and Physical Science Test (EPST) at The Pennsylvania State College, Sackett (1940) recognized the need for "better counseling," as part of the selection process for students considering engineering. More recently, Wankat (1986) has pointed out the need to improve the academic advising of engineering students.

While the use of massive test batteries measuring a wide range of intellective variables has declined over the years, there has been a recent recognition of the importance of non-intellective factors related to success in engineering programs of study (LeBold, 1958). Early attempts to examine non-intellective variables relied on existing psychometric instruments; for example, Elton and Rose (1967) utilized the Omnibus Personality Inventory while Elkins and Luetkemeyer (1974) employed the California Psychological Inventory and the Holland Vocational Preference Inventory as measures of non-intellective variables. Similarly, Taylor and Hanson (1972) utilized the Strong Vocational Interest Blank for this purpose.

The present study differs in a number of basic ways from previous studies. In the area of academic performance, not only general performance but also performance in specific courses considered vital for success in engineering was studied. In regard to persistence in engineering, not only persistence but also successful persistence was studied along with unsuccessful persistence and successful non-persistence in engineering. In contrast with studies which have utilized general psychometric instruments, assessments of non-intellective variables were obtained through student responses on specially designed self-report inventories and through interviews conducted by trained professional advisers.

STATEMENT OF THE PROBLEM

Students are most likely to function well academically and make sound educational decisions when they clearly understand how their interests, abilities and academic performance fit with the educational characteristics of their chosen fields of study. When the educational plans of college students are unduly influenced by non-personal external factors, the risk of inappropriate planning is increased significantly. This situation frequently exists with many students who choose baccalaureate engineering programs of study. Based mainly on excellent employment opportunities, enrollments in these programs have increased by approximately 70% in the last decade (Ellis, 1985). As a consequence of this increase, a disproportionate number of students are selecting baccalaureate engineering programs for inappropriate reasons. Often these choices are based solely on extrinsic reasons such as employment opportunities, monetary rewards and status. Such motives by themselves are not likely to support persistence and success in baccalaureate engineering programs. Often such motives are coupled with a lack of adequate ability and genuine interest in mathematics and science, as well as a misconception of the engineering curriculum and the world of work of engineers (Dickason, 1969; Springob, 1974).

Currently there is a national attrition rate of approximately 50% for college students pursuing engineering majors (Hayden and Holloway, 1985). Much of this attrition may be attributed to inappropriate educational planning. For the students involved in this attrition, there is a costly and time consuming consequence which is often accompanied by emotional stress both for students and their families. In addition, this high attrition rate contributes significantly to the overall retention concerns of the institutions involved.

Current educational practices related to this problem, especially counseling and advising at the secondary and post secondary levels, are both inappropriate and inadequate. They are inappropriate because they do not address many of the characteristics of individual students which relate to persistence and success in their intended educational fields. They are inadequate because information on many of the individual student variables that predict both persistence and success in engineering is not available for academic advising purposes.

Consequently, advising focuses on course requirements for specific majors with little attention given to the individual student's interests, abilities, and appropriateness of educational plans. Thus, the present approach to academic advising is not student-centered.

Although this is a national issue, very few studies have been conducted which address a wide range of both intellective and non-intellective variables related to both persistence and success in engineering. As Hayden and Holloway (1985) pointed out, research has not provided guidelines for the identification of students at risk for attrition. Most research has focused on a limited number of intellective variables as they relate to academic performance and attrition (Rezak, 1988). However, Durio, et. al., (1980) recognized that it was more difficult to predict persistence than to predict academic performance, and suggested that a variety of non-intellective variables be studied in addition to intellective ones as predictors of both persistence and academic performance. Although some researchers have examined a variety of non-intellective variables (Beronja and Bee, 1986; Foster, 1976; Lent, et. al., 1986; Marks, 1970; Taylor and Whetstone, 1983, Wyckoff, 1982), no studies of a comprehensive nature have been conducted examining a broad range of both intellective and non-intellective variables.

The identification of predictors of persistence and success in engineering programs of study has important implications for counseling and advising (LeBold, 1958). Such predictors can become significant advising tools which can be used to actively involve students in the advising process (Hayden and Holloway, 1985). Thus, students can be assisted in accurately assessing their personal interests and abilities with respect to the likelihood of their persisting and being successful in engineering programs of study. Such applications of predictor information in the advising process is basically consistent with the "identify and consult model" (Hayden and Holloway, 1985), which assists students in an early evaluation of their choice of engineering with the identification of specific areas of risk for success in engineering programs of study.

An explicit assumption is being made in conjunction with this study concerning the usefulness of predictor information in academic advising, i.e., students are more likely to function well academically and make sound educational decisions when they clearly understand how their personal characteristics relate to the likelihood that they will persist successfully in their chosen field of study. By being well informed, students will be better able to choose early in their educational careers, those curricular paths which fit their interests and abilities.

PURPOSE

The purpose of this study was to develop predictive models of persistence and success in baccalaureate engineering at the end of the sophomore year by analyzing eleven intellective and nine non-intellective variables in relation to these criteria.

The long-term outcome can contribute significantly to the improvement of academic advising for students considering engineering majors and thus can improve student retention.

METHOD

Data Source

The 1984 entering freshman class in the College of Engineering at The Pennsylvania State University served as the population for this study. From a total class of 1605, data were obtained on 1220 students. Because of unusable data the final sample size was 1043, representing 65% of the population.

Data Collection

The Freshman Testing, Counseling and Advising Program (FTCAP) is provided for all entering freshmen at The Pennsylvania State University. This Program has two stages, one day each: 1) testing and 2) counseling and advising. These two stages, plus undergraduate admissions office records and transcript information after two years of enrollment, provided the data for this study. Table 1 lists the dependent and independent variables, a description of the variables, their measurement levels and the data source for each variable. There were four sources of data for the study.

1. Admissions Records: SAT Scores (SATM, SATV) High School Grade Point Averages (HSGPA), and Gender (GEN) were obtained from admissions records. For purposes of admission, high school grade point averages are based upon grades in academic courses only and are converted to a 0.0 to 4.0 scale.

2. Freshman Testing, Counseling and Advising Program - Testing Phase: Both intellective and non-intellective data were obtained through this phase of the program. Intellective data were in the form of selective placement scores on a battery of tests, including Algebra (ALG) and Chemistry (CHEM-S) administered to all freshmen admitted to the University. The Mathematics Test (algebra) was developed by the Mathematics Association of America, the Chemistry Test was developed by the University's Chemistry Department. The results of these tests, which measure mathematics and science achievement, determine beginning level course work in mathematics and chemistry.

In addition to the placement examinations, all freshmen are required to complete a comprehensive Educational Planning Survey. The survey requests that students provide detailed information regarding high school academic experiences, expectations and concerns about college, educational and occupational plans, and reasons for attending college. This information, which is used in the Counseling and Advising phase of the program, provided some of the non-intellective data. This included expected number of College Study Hours (ST), and Non-Science Points (NSPTS) which is a measure of a student's consistency of major choice as measured by the student's assignment of points (out of 100) to non-science versus science majors. A copy of The Educational Planning Survey is in Appendix 1.

3. Freshman Testing, Counseling and Advising Program - Counseling and Advising Phase: This phase, which constitutes the first stage of academic advising for all freshmen, provides each student an individualized academic advising interview with a professional academic adviser. The purpose of the interview is to assist new freshmen in evaluating their educational plans by relating their personal characteristics such as abilities, academic preparation and interests to their intended program of study.

Selected academic advisers were trained to conduct the interviews in order to obtain data on the following student non-intellective variables: Attitudes Towards High School Mathematics, Physics and Chemistry (MATH, PHYS, CHEM); Reason for Engineering Choice (REAS); Certainty regarding their intended major (CERT); and Knowledge of their intended major (KNOW). The measurement levels of each variable are listed in Table 1. The interview data collection form and the adviser training manual are in Appendix 2.

4. Transcripts and Registration Information: Data on the dependent variables, Engineering Foundation Grade Point Average after two years (EFGPA), Calculus I Grade (M140), Calculus II Grade (M141), Physics I Grade (P201), Physics II Grade (P202) and Chemistry I Grade (C12) and Enrollment Status after one year (STATUS) were obtained from student transcripts and registration (class schedules) information. Table 1 lists the measurement levels for these variables.

Sophomore Status

Table 2 provides the enrollment status for the original freshman engineering class at the end of the sophomore year. Table 3 shows changes in enrollment for the freshman to the sophomore year.

TABLE 1: DESCRIPTIONS OF VARIABLES

VARIABLE NAMES	VARIABLE DESCRIPTION	MEASUREMENT LEVEL	SOURCE OF DATA
Dependent Variables			
Cumulative Grade Point Average (CGPA)	overall grade point average after one year	continuous variable (0.00 to 4.00)	student transcripts
Engineering Grade Point Average (EGPA)	grade point average in required mathematics, physics, and chemistry courses after one year	continuous variable (0.00 to 4.00)	student transcripts
Sophomore Enrollment Status (SOPHST)	enrollment status after two years	. persisting successfully in engineering (ENGR) . science/mathematics oriented baccalaureate program (SCBAC) . non-science baccalaureate program (NSBAC) . associate program (ASSOC) . nondegree (NDEG) . discontinued enrollment (DISC) . academically dropped (DROP)	student transcripts and registration data

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TABLE 1: DESCRIPTION OF VARIABLES (con't)

VARIABLE NAMES Independent Variables - Intellective	VARIABLE DESCRIPTION	MEASUREMENT LEVEL	SOURCE OF DATA
High School Grade Point Average (HSGPA)	converted grade point average based on high school academic courses only	continuous variable (0.00 to 4.00)	admission records
Scholastic Aptitude Test Score Mathematics (SATM)		continuous variable (200 to 800)	admission records
Scholastic Aptitude Test Score Verbal (SATV)		continuous variable (200 to 800)	admission records
Algebra Score (ALG)	subscore of University's mathematics placement test	continuous variable (0 to 32)	FTCAP - testing phase
Chemistry Score (CHEM-S)	score on University's chemistry placement test	continuous variable (0 to 20)	FTCAP - testing phase
Engineering Foundation Grade Point Average (EFGPA)	grade point average for Calculus I, II, Physics I, II and Chemistry I	continuous variable (0.00 to 4.00)	student transcripts
Calculus I Grade (CALC I)	grade in Calculus I	.A .B .C .D .F	student transcripts

TABLE 1: DESCRIPTION OF VARIABLES (con't)

VARIABLE NAMES Independent Variables - Intellective	VARIABLE DESCRIPTION	MEASUREMENT LEVEL	SOURCE OF DATA
Calculus II Grade (CALC II)	grade in Calculus II	.A .B .C .D .F	student transcripts
Physics I Grade (PHYS 1)	grade in Physics I	.A .B .C .D .F	student transcripts
Physics II Grade (PHYS II)	grade in Physics II	.A .B .C .D .F	student transcripts
Chemistry I Grade (CHEM I)	grade in Chemistry I	.A .B .C .D .F	student transcripts

TABLE 1: DESCRIPTION OF VARIABLES (con't)

VARIABLE NAMES	VARIABLE DESCRIPTION	MEASUREMENT LEVEL	SOURCE OF DATA
Independent Variables Non-Intellective			
Gender (GEN)		· male · female	admission records
Attitude Towards High School Mathematics (MATH)	students' reactions to high school mathematics	. like . indifferent/dislike	FTCAP - counseling and advising phase
Attitude Towards High School Physics (PHYS)	students' reactions to high school physics	. like . indifferent/dislike	FTCAP - counseling and advising phase
Attitude Towards High School Chemistry (CHEM)	students' reactions to high school chemistry	. like . indifferent/dislike	FTCAP - counseling and advising phase
College Study Hours (ST)	anticipated college study hours per week	continuous variable (0 to 60)	FTCAP - testing phase
Non-science Points (NSPTS)	consistency of major choices	continuous variable (0 to 100)	FTCAP - testing phase
Reason for Engineering Choice (REAS)	intrinsic (genuine) vs extrinsic (superficial) reasons	. genuine . superficial	FTCAP - counseling and advising phase
Certainty (CERT)	expressed certainty regarding intended major	. very certain . about 50/50 . slightly uncertain . uncertain	FTCAP - counseling and advising phase
Knowledge of Intended Major (KNOW)	accuracy of student's knowledge of engineering major	.accurate .inaccurate	FTCAP - counseling and advising phase

TABLE 2: SOPHOMORE STATUS (SYSTEMWIDE):

NUMBER AND PERCENT OF THE TOTAL FRESHMAN ENGINEERING CLASS IN EACH STATUS

SOPHOMORE STATUS

	ASSOC	DISC	DROP	ENGR	NDEG	NSBAC	SCBAC	TOTAL
N	35	154	44	510	10	175	115	1043
%	3.36	14.77	4.22	48.90	0.96	16.78	11.03	100.00

TABLE 3: CHANGES IN ENROLLMENT STATUSES, FRESHMAN TO SOPHOMORE YEAR

	FRESHMAN		SOPHOMORE	
	N	%	N	%
Continuing in Engineering	749	71.75	510	48.90
Continuing in Non-Engineering Baccalaureate	182	17.44	290	27.80
Non-Continuing-Baccalaureate (Assoc, Nondegree, Dropped, Withdrew)	113	10.81	243	23.20
TOTAL	1044*	100.00	1043*	100.00

*totals disagree - inability to locate sophomore data

Statistical Analysis

As listed in Table 1, Sophomore Enrollment Status (SOPHST) was the dependent variable. The nineteen intellective and non-intellective independent variables are also listed in Table 1.

For purposes of analysis, "persistence and success" in engineering was defined as students who qualified for an engineering major at the end of the sophomore year and enrolled in an engineering major in the first semester of their junior year.

Three models were developed. Each model predicted sophomore persistence and success at a different point in time. The first model used those variables available at pre-enrollment prior to the start of the freshman year. This set included all of the intellective and non-intellective measures.

The second model used all of the intellective and non-intellective variables as well as the grades in Calculus I, Physics I and Chemistry I. Typically students complete these courses by the end of the freshman year.

The third model used all of the variables in the previous model as well as the grades in Calculus II and Physics II. These courses are usually completed by the end of the third semester.

The discrete dependent variable STATUS was analyzed in terms of logit models. The log odds of the status ratio of PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY VERSUS ALL OTHER ENROLLMENT STATUSES was assumed to be estimated as linear combination of the independent variables (fourteen for model I; seventeen for model II; nineteen for model III). The models were built using the CATMOD procedure in SAS, using maximum-likelihood estimation of the model parameters (Statistical Analysis System, 1985). The significance level for entry of a variable into the model was set at P = .10. The variables ALG, HSGPA, NSPTS and CHEM were treated as continuous variables and modeled with a single parameter.

FINDINGS

At the end of the sophomore year 510 students (48.90%) of the 1043 who began in engineering were in an engineering major (71 of 176 females = 40.34%, 439 of 867 males = 50.36%). Table 2 provides a frequency distribution of all enrollment statuses at the end of the sophomore year.

Table 3 shows changes in enrollment statuses from the end of the freshman year to the end of the sophomore.

Each model identified significant predictor variables for given points in time: pre-enrollment, freshman year and sophomore year.

Model I - Pre-Enrollment Variables (Intellective and Non-intellective): The logistic regression model that best predicts the log odds of the ratio as the status PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY TO ALL OTHER ENROLLMENT STATUSES included five of the fourteen eligible independent variables. In order of the contribution to the total chi-square these are High School Grade Point Average (HSGPA), Algebra Score (ALG), Gender (GEN), Non-Science Points (NSPTS), Chemistry Score (CHEM), and Reason for Engineering Choice (REAS). (Table 4).

Model II - Pre-Enrollment Variables plus grades in Calculus I, Physics I and Chemistry I: The logistic regression model that best predicted the log odds of PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY TO ALL OTHER ENROLLMENT STATUSES included three of the seventeen eligible independent variables. Listed in order of contribution to the total chi-square these are grades in Physics I (P201), Calculus I (M1[illegible]), and Chemistry I (C12). (Table 5).

Model III - Pre-Enrollment Variables plus grades in Calculus I and II, Physics I and II, and Chemistry I: The logistic regression model that best predicted the log odds of PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY TO OTHER ENROLLMENT STATUSES included three of the nineteen eligible independent variables. In order of contribution to the total chi-square these are grades in Calculus II (M141), Physics II (P207), and Physics I (P201). (Table 6).

DISCUSSION

The three models that predict students qualifying for and choosing to enroll in a major in the College of Engineering at the end of the sophomore year indicate that the predictive variables are not constant over time. As students progress through the first two years of college and more data becomes available (academic performance), variables which at an earlier point in time were predictive are replaced by new variables. Therefore the model which is

TABLE 4: Model I - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. All Other Enrollment Statuses at the End of the Sophomore Year

EFFECT	D'	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	-4.665	44.73	.0001*
HSGPA	1	0.751	14.63	.0001*
ALG	1	0.055	10.97	.0009*
GENDER	1		10.07	.0015*
MALE		0.314		
FEMALE		-0.314		
NSPTS	1	-0.016	8.85	.0029*
CHEM	1	0.053	6.82	.0090*
REASON	1		5.93	.0149*
GENUINE		0.223		
SUPERFICIAL		-0.233		

*P≤.10

TABLE 5: Model II - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. All Other Enrollment Statuses at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	-0.731	9.25	.0024*
PHYS I	2		72.55	.0001*
A/B		1.046		
C		0.130		
D/F		-1.176		
CALC I	2		32.39	.0001*
A/B		0.744		
C		-0.084		
D/F		-0.660		
CHEM I	4		24.46	.0001*
A		1.082		
B		0.648		
C		0.169		
D		-0.720		
F		-1.179		

*P≤.10

TABLE 6: Model III - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. All Other Enrollment Statuses at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	0.016	0.01	.9350
CALC II	2		38.34	.0001*
A/B		0.918		
C		0.174		
D/F		-1.092		
PHYS II	4		35.95	.0001*
A		1.479		
B		0.874		
C		0.241		
D		-0.618		
F		-1.976		
PHSY I	2		7.58	.0226*
A/B		0.459		
C		0.083		
D/F		-0.542		

*$P \leq .10$

used for any individual student is determined by the data which is available.

Thus in the case of a student who has not yet begun college the pre-enrollment variables of high school grade point average (HSGPA), algebra score (ALG), gender (GEN), non-science points (NSPTS), chemistry score (CHEM) and reason for choosing engineering (REASON) are the predictors of status. Typically after the freshman year when the student has completed Physics I, Calculus I and Chemistry I, grades in these courses replace the pre-enrollment variables as predictors. As a student completes the sophomore year and has taken Physics II and Calculus II the new predictors become grades in Calculus II, Physics II and Physics I. This is consistent with the finding that the grades in mathematics and science courses are good indicators of potential success in future engineering courses (Jakabowski et. al., 1988).

To the authors' knowledge the only previous study that attempted to predict simultaneously both persistence and success in engineering using both intellective and non-intellective variables was Levin and Wyckoff, 1988. This study used the same population as the present study, and used pre-enrollment variables to predict persistence and success in engineering at the end of the freshman year. With a few exceptions the same pre-enrollment variables that predicted persistence and success at the end of the freshman year also predicted students qualifying for and deciding to enroll in a major in the College of Engineering at the end of the sophomore year. However, the order of the predictors' contributions to the total chi-square did change.

In the case of sophomore predictions, the SAT verbal score was not significant whereas it had a slightly negative effect as a freshman year predictor. The two most prominant variables, the algebra score (ALG) and high school average (HSGPA), changed positions with the HSGPA being the most predictive for the sophomore year. However, the most noteworthy change was gender (GENDER) which was the least predictive for the freshman year, but became the third most important variable for the sophomore year, with males being more likely to successfully persist than females. The variables non-science points (NSPTS), chemistry score (CHEM) and reason for choosing engineering (REASON) remained in the same positions relative to each other. Students with genuine reasons for choosing engineering were more likely to successfully persist than those with superficial reasons.

The two variables that contribute most to predictive Model I (high school average, algebra score) are intellective and reflect general academic achievement as well as specific achievement in mathematics. Such variables typically reflect the use of abilities over a period of time, which is determined by such personal student characteristics as motivation, attitudes and study habits. Such variables are well-established predictors of overall academic performance in science-oriented programs of study (Durio, et. al, 1980; Wyckoff, 1982). These findings demonstrate a commonly held belief that the best predictor of future behavior is past behavior. However, in this study these variables are predicting not only academic performance, but also a student's decision to enroll in a College of Engineering major after the completion of the sophomore year. Although it is acknowledged that academic performance may contribute to a student's decision to persist in any given major, there are always students who do not persist in engineering even though they achieve at high levels. The complex interaction between persistence and academic performance is an area that requires further study.

A noteworthy outcome of this research is the finding that the variables which are predictive depend on the student's point of progress through the first two years of an Engineering program. The pre-enrollment variables of Model I (both intellective and non-intellective) are all replaced by academic performance variables in Models II and III as a student progresses through an engineering program. A reasonable hypothesis (to be tested in a future study) is that performance in calculus, physics and chemistry is a function of the pre-enrollment characteristics of students.

The models that predict PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY compared to a number of other enrollment statuses (ANY BACCALAUREATE, NONSCIENCE BACCALAUREATE, and SCIENCE BACCALAUREATE PROGRAMS) are presented the Appendices 1, 2, and 3.

IMPLICATIONS

Currently, there is evidence of increasingly serious shortages of engineers and scientists (National Science Foundation, 1987; National Research Council, 1985). "Under present circumstances, projected student demographic trends will not produce enough scientists and engineers to meet the nation's needs" (Council on Research and Technology, 1989 p ii). In addition, women and minorities continue to be underrepresented in these fields (Council on Research and Technology, 1989). For females this occurs not only at the point of admission but as this study shows women are less likely to persist successfully in engineering even though on all other independent variables examined they are essentially the same as males.

Academic advising has long been recognized as being important for student retention. Given engineering programs' high attrition rates, the noted future shortages in the engineering profession and the underrepresentation of women and minorities, the role of academic advising takes on increased importance (Levin and Wyckoff, 1988; Levin and Wyckoff, 1989b; Woodside and Snyder, 1989; Wankat, 1986).

The authors contend that the goal of academic advising is to assist students to make <u>informed decisions</u> regarding educational alternatives. Such informed decisions maximize the likelihood of a <u>congruent fit</u> between a student's personal characteristics and the educational program being considered. Such congruency increases the probability that students will

1 Does student understand relevant self variables?	1 Does student understand relevant educational variables?	1 Does student understand the relationship between self and educational variables?	2 Does student select a "best fit" educational program?	Type of Decision
Yes	Yes	Yes	Yes	informed - congruent
Yes	Yes	Yes	No	informed - incongruent
No	No	No	No	uninformed - incongruent
No	No	No	Yes	uninformed - congruent

Note: Other combinations are possible however the following conditions always hold:

1 - a "no" in any of these areas determine an "uninformed" decision type

2 - a "no" in this column determines an "incongruent" decision type

FIGURE 1: EXAMPLES OF TYPES OF STUDENT DECISIONS

persist and be more successful in their chosen fields of study. Informed decision making occurs when a student understands their relevant personal variables, the relevant educational variables and the relationship between these. Congruency exists in a decision when a student possesses the personal characteristics which fit the characteristics of a chosen field of study, i.e., which predict persistence and success in that field of study. Therefore a congruent informed decision exists when there is a "fit" and the student understands this relationship (Badiali, Higginson, Levin, and Wyckoff, 1989). Figure 1 illustrates types of decisions as determined by the student's understanding of relevant variables and a decision to pursue any given major.

Students are placed at risk for persistence and success when educational decisions are incongruent (Rezak, 1988). They are placed at maximum risk when decisions are both incongruent and uninformed.

High risk decisions on the part of students are more likely to occur when the practice of advising is not informed by research that identifies the relevant student and program variables related to persistence and success. In addition, high risk decisions can also occur when the goals of advising are not directed towards student informed decision making (Levin and Wyckoff, 1989).

This study reduces the potential for high risk decisions on the part of students considering engineering programs by providing academic advisers with empirical data that identifies those variables that predict persistence and success in engineering. These findings allow for assessment statements to be made about an individual student's degree of congruency with engineering programs of study. These assessment statements are in the form of probabilities of persisting successfully in engineering, and are based on the relationship of the individual student's personal characteristics to those of students who persist successfully.

The probability statements are the solutions to the three logistic regression equations. To illustrate the applications of the three models, a hypothetical student with the following characteristics is used:

PRE-ENROLLMENT	FRESHMAN YEAR	SOPHOMORE YEAR
HSGPA = 3.0	CALC I = B	CALC II = C
ALG = 25	PHYS I = B	PHYS II = C
GENDER = male = M	CHEM I = C	
NSPTS = 10		
CHEM = 12		
REASON = Genuine = G		
CALC I = B		
CALC II = C		
PHYS I = B		
PHYS II = C		
CHEM I = C		

MODEL I: PRE-ENROLLMENT VARIABLES PREDICTING ENROLLMENT STATUS AT THE END OF THE SOPHOMORE YEAR

At the pre-enrollment point in time the equations that predict the natural log odds of this student persisting successfully in engineering (PSE) vs. all other statuses (AOS) is derived from the significant variables of Model I in Table 4.

$$\ln \frac{PSE}{AOS} = -4.665 + .751 \times (HSGPA) + .055 \times (ALG) + .314 \times (GENDER = M) - .016 \times (NSPTS) + .053 \times (CHEM) + .223 \times (REASON = G)$$

$$\ln \frac{PSE}{AOS} = -4.665 + .751(3.00) + .055(25) + .314(1) - .016(10) + .053(12) + .22\text{'}\ \text{'})$$

$$= -.0.024$$

$$\text{Odds } \ln \frac{PSE}{AOS} = e^{-0.024} = 2.72^{-0.024} = \frac{.976}{1}$$

Therefore, at the pre-enrollment point in time the probability of persisting successfully in engineering vs. all other statuses at the end of the sophomore year for this student is $= \frac{.976}{1.976} = 49\%$

MODEL II: FRESHMAN YEAR PREDICTING ENROLLMENT STATUS AT THE END OF THE SOPHOMORE YEAR

After the completion of CALC I, PHYS I and CHEM I the equation that predicts the natural log odds of this student persisting successfully in engineering (PSE) vs. all other statuses (AOS) at the end of the sophomore year is derived from the significant variables of Model II in Table 5.

$$\ln \frac{PSE}{AOS} = -.731 + 1 \times (PHYS\ I = B) + 1 \times (CALC\ I = B) + 1 \times (CHEM\ I = C)$$

$$\ln \frac{PSE}{AOS} = -.731 + 1(1.046) + 1(0.744) + 1(0.169)$$

$$= 5.14$$

$$\text{Odds} \ln \frac{PSE}{AOS} = e^{1.678} = 2.72^{1.678} = \frac{5.36}{1}$$

Therefore, after the completion of CALC I, PHYS I and CHEM I the probability of persisting successfully in engineering vs. all other statuses at the end of the sophomore year for this student is $= \frac{5.36}{6.36} = 84\%$

MODEL III: SOPHOMORE YEAR VARIABLES PREDICTING ENROLLMENT STATUS AT THE END OF THE SOPHOMORE YEAR

After the completion of CALC II, and PHYS II the equation that predicts the natural log odds of this student persisting successfully in engineering (PSF) vs. all other enrollment statuses (AOS) is derived from the significant variables of Model III in Table 6.

$$\ln \frac{PSE}{AOS} = .016 + 1 \times (CALC\ II = C) + 1 \times (PHYS\ II = C) + 1 \times (PHYS\ I = C)$$

$$\ln \frac{PSE}{AOS} = .016 + 1(.174) + 1(.241) + 1(.083)$$

$$= 5.14$$

$$\text{Odds} \ln \frac{PSE}{AOS} = e^{.514} = 2.72^{.514} = \frac{1.673}{1}$$

Therefore after CALC II and PHYS II have been completed the probability of persisting successfully in engineering vs. all other status at the end of the sophomore year for this student is $= \frac{1.673}{2.673} = 62\%$

CONCLUSIONS

In conclusion, to maximize the efficacy of advising, the practice should be informed by empirical research. This study moves the advising of engineering students in this direction. Students need valid and reliable information to make informed decisions; likewise advisers need the same information to engage effectively in the advising process. To the extent that such information is not available, students and adviser are forced to operate at an intuitive level. To the extent that advising is based on intuition, students may be put at risk for persistence and success in engineering programs of study (Levin and Wyckoff, 1989b).

These models would be used most efficiently by developing an interactive computer program to assist in the advising process. Pilot attempts by the authors to design computer-assisted approaches for the use of the models have been initiated. It is stressed, however, that the use of these models through an interactive computer program should not be offered in isolation from the usual one-to-one advising approaches. Also, a standard caution which should be observed whenever statistical data are used in advising the individual student is that any individual case may be an exception to even the most compelling statistics. Therefore, such data should always be placed in the context of more complete personal information about the individual student (Wyckoff, 1982).

It is suggested that future research in studying persistence and success in engineering take a number of specific directions. The differential rate of persisting successfully between males and females is currently unexplained. For example what are the differences between these women who are academically successful but choose to leave engineering versus these who are academically successful but choose to remain? How do social/environmental variables affect this choice. Why do proportionally fewer academically qualified women than men choose engineering?

Since the predictor variables change over time how are preenrollment variables related to those variables that predict at later points in time?

Finally, attention needs to be addressed to how the findings of this study can be best utilized in academic advising strategies. How would more sophisticated measures, especially in the non-intellective areas, improve predictability? For example, preliminary investigations by the authors using existing scales (Fennema & Sherman, 1976) that measure students' attitudes towards mathematics have been shown to differentiate students in relation to their educational plans.

APPENDIX 1

LOGISTIC REGRESSIONS FOR PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY VS. ANY OTHER BACCALAUREATE PROGRAM ENROLLMENT AT THE END OF THE SOPHOMORE YEAR

- MODEL I
- MODEL II
- MODEL III

TABLE 7: Model I - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Any Other Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	-1.488	12.77	.0004*
NSPTS		-0.019	8.71	.0032*
NSEX	1		8.70	.0032*
MALE		0.311		
FEMALE		-0.311		
NREAS	1		7.29	.0069*
GENUINE		0.276		
SUPERFICIAL		-0.276		
ALG	1	0.051	7.18	.0074*
NPHYS			3.29	.0697*
LIKE		0.199		
INDIFF/DISLIKE		-0.199		
CHEM	1	0.041	2.98	.0844*

*P≤.10

TABLE 8: Model II - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Any Other Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	1.871	8.42	.0037*
PHYS I	3		54.50	.0001*
A		1.217		
B		0.527		
C		-0.302		
D/F		-1.442		
CALC I	2		30.01	.0001*
A/B		0.810		
C		-.123		
D/F		-.687		
CHEM I	2		15.21	.0005*
A/B		0.683		
C		0.149		
D/F		-.832		
SATV	1	-0.003	7.61	.0058*

*P≤.10

TABLE 9: Model III - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Any Other Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	0.758	17.44	.0001*
CALC II	2		26.95	.0001*
A/B		0.798		
C		0.253		
D/F		-1.051		
PHYS II	3		24.57	.0001*
A		1.116		
B		0.384		
C		-0.190		
D/F		-1.310		
PHYS I	3		6.69	.0823*
A		0.577		
B		0.183		
C		-.034		
D/F		-.726		
KNOW	1		4.83	.0280*
ACCURATE		0.287		
INACCURATE		-0.287		

*P≤.10

APPENDIX 2

LOGISTIC REGRESSIONS FOR PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY VS. SCIENCE BACCALAUREATE PROGRAM ENROLLMENT AT THE END OF THE SOPHOMORE YEAR

- MODEL I
- MODEL II
- MODEL III

TABLE 10: Model I - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs Science Baccalaureate Program Enrollment at the End of the Sophpmore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	-0.630	1.58	.2084
NPHYS	1		12.76	.0004*
LIKE		0.450		
INDIFF/DISLIKE		-0.450		
ALG	1	0.071	11.48	.0007*
NSEX	1		5.13	.0235*
MALE		0.303		
FEMALE		-0.303		

*P≤.10

TABLE 11: Model II - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Science Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	1.281	57.87	.0001*
PHYS I	3		31.43	.0001*
A		1.031		
B		0.556		
C		-0.326		
D/F		-1.261		
CALC I	2		18.04	.0001*
A/B		0.746		
C		-0.259		
D/F		-0.487		

$*P \leq .10$

TABLE 12: Model III - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Science Baccalaureate Program of Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	0.510	3.68	.0551*
PHYS II	2		13.50	.0012*
A/B		0.878		
C		-0.067		
D/F		-0.811		
CALC II	1		7.89	.0050*
A/B/C		0.591		
D/F		-0.591		
CALC I	2		7.45	.0242*
A/B		0.614		
C		-0.114		
D/F		-0.500		
PHYS I	2		6.48	.0391*
A/B		0.521		
C		0.174		
D/F		-0.695		
NKNOW	1		3.53	.0601*
ACCURATE		0.306		
INACCURATE		-0.306		

*$P \leq .10$

APPENDIX 3

LOGISTIC REGRESSIONS FOR PERSISTING IN BACCALAUREATE ENGINEERING SUCCESSFULLY VS. NON-SCIENCE BACCALAUREATE PROGRAM ENROLLMENT AT THE END OF THE SOPHOMORE YEAR

- MODEL I
- MODEL II
- MODEL III

TABLE 13: Model I - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Non-Science Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	0.623	.78	.3783
NSPTS	1	-0.022	11.06	.0009*
SATV	1	-0.003	6.50	.0108*
NREAS	1		6.47	.0110*
GENUINE		0.301		
SUPERFICIAL		-0.301		
ALG	1	0.055	4.64	.0312*
NSEX	1	0.266		
MALE		-0.266		
FEMALE				
	1		4.17	.0410*
CHEM		0.060		

*P≤.10

TABLE 14: Model II - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Non-Science Baccalaureate Program Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	4.456	24.97	.0001*
PHYS I	3		43.30	.0001*
A		1.584		
B		0.504		
C		-0.326		
D/F		-1.762		
CALC I	2		25.50	.0001*
A/B		0.938		
C		-0.013		
D/F		-0.923		
CHEM I	3		16.89	.0007*
A		0.948		
B		0.392		
C		0.075		
D/F		1.415		
SATV	1	-0.007	16.19	.0001*

*P≤.10

TABLE 15: Model III - Logistic Regression for Persisting in Baccalaureate Engineering Successfully vs. Non-Science Baccalaureate Program of Enrollment at the End of the Sophomore Year

EFFECT	DF	ESTIMATE	CHI-SQ	PROB
INTERCEPT	1	5.772	0.00	.9747
CALC II	3		34.25	.0001*
A		1.172		
B		0.809		
C		-0.304		
D/F		-1.577		
PHYS II	3		12.80	.0051*
A		12.748		
B		-3.653		
C		-3.839		
D/F		-5.256		

*$P \leq .10$

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